SDO/EVE Spectra of Solar Flares

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OBSERVATIONS

Solar Dynamics Observatory (SDO) carries the full-disk EUV spectrograph EVE (EUV Variability Experiment) which is capable of recording the EUV spectra of the Sun-as-a-star with high cadence (Woods et al. 2012). Although this instrument was designed primarily for solar variability studies (i.e. the irradiance variability), it is also well suited for solar flare observations. The reason is that, contrary to optical spectra, the EUV full-disk spectrum clearly resembles flares. This is because the lines and resonance continua are strongly enhanced during a flare and thus even with a small flaring area the full-disk flux is affected. This is clearly demonstrated in a recent paper by Milligan et al. (2012), which describes the EVE observations of an X-type flare of 15 Feb 2011. This flare was detected by both MEGS-A (grazing incidence) and MEGS-B (normal-incidence) spectrometers in the wavelength range 65-370 Å and 370-1050 Å, respectively. Moreover, MEGS-P, a broadband (100 Å) diode, covered the hydrogen Lα integrated flux. The flare spectra were obtained by subtracting the pre-flare spectrum from the full-disk spectrum taken during the flare (see example of the HI Lyman continuum in Fig. 1).

In this study we show the preliminary results of our non-LTE modeling of observed resonance continua of the hydrogen and helium, i.e. the Lyman continua of HI (912 Å), HeI (504 Å) and HeII (228 Å). Moreover, we discuss the hydrogen Lα line. We try to compare our results with flare spectra of Milligan et al. (2012).

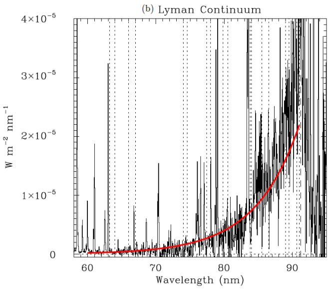

Figure 1

HI Lyman continuum flux at flare maximum (from Milligan et al. 2012)

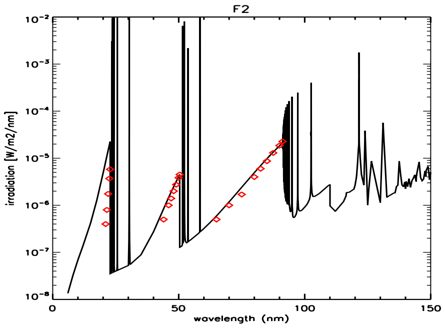

Figure 2

Spectral flux computed from the flare model F2. All three resonance continua are well distinguished, along with some strong lines. Red diamonds show the observed continua. Both spectra have been aligned such that the fluxes fit at the HeI 504 Å continuum head (the HeI continuum seems to be the most reliable one, see Milligan et al. 2012).

SYNTHETIC SPECTRA

To synthesize the snapshot of resonance continuum spectra, we used the semiempirical flare model F2 from Machado et al. (1980), which corresponds to a medium-strong flare. The PANDORA non-LTE code was used to compute the spectrum shown in Fig. 2. The fit of the synthetic and observed spectra is possible only to within a constant shift on the log-scale in Fig. 2 because we don't know the actual flare area and thus the solid angle under which the flare is seen from the Earth (this is a general problem for flare stars). The alignment in Fig. 2 shows an excellent relative agreement for both HI and HeII continua. However, the HeII continuum doesn't fit, which can be caused either by difficulties in recognizing its true shape hidden in a strongly blended area, or by oversimplified transfer modeling of HeII continuum formation in flares. Also the F2 may not be appropriate for the formation region of HeII continuum, it was constructed on basis of HI Lyman-continuum flare spectra. An interesting feature detected by EVE is enhanced free-free continuum (due to hot flare-loop plasma) , which may affect the HeII photoionization. The alignment we used allows us to derive the flare area which amounts to about 1.5×10^8 km^2 . This is rather small compared to typical Hα flare kernels, but high-energy kernels (e.g. WLF) are usually smaller. In order to increase this area, one would need lower intensities consistent with less energetic flares. This would contradict the fact that the studied flare was of an X-type. Our comparison is made for the snapshot taken at the flare maximum (both GOES and HXR, see Fig. 3 in Milligan et al. 2012). This indicates that the electron beams may be important and thus the non-thermal excitation and ionization of hydrogen and possibly helium can play a role. On the other hand, the light curves shown by Milligan et al. (2012) suggest that the continuum spectra will be similar also in later times when the beams are not expected. This is especially true for helium continua which, contrary to the hydrogen one, don't exhibit an impulsive behavior. Different situation is with the hydrogen Lα line, which seems to show impulsive peaks and they may be related to the non-thermal processes, namely the strong non-thermal collisional excitation of the second hydrogen atomic level. In fact, our computed Lα integrated flux is lower compared to that observed at the flare maximum and the electron beams may lead to its substantial enhancement.

CONCLUSIONS

We made a first comparison of the SDO/EVE flare spectra with simplified transfer modeling. We have shown that even the static 1D model allows a reasonable quantitative comparison between the observed and synthetic spectra. However, the flare evolution, and namely during the impulsive phase, will require more sophisticated modeling and finally the fully radiation-hydrodynamical simulations (Allred et al. 2005, Kašparová et al. 2009).

References:

Allred, J.C., Hawley, S.L., Abbett, W.P. and Carlsson, M. 2005, ApJ 630, 573
Kašparová, J., Varady, M., Heinzel, P. et al. 2009, A&A 499, 923
Machado, M.E., Avrett, E.H., Vernazza, J.E. and Noyes, R.W. 1980, ApJ 242, 336
Milligan, R. O., Chamberlin, P.C., Hudson, H.S. et al. 2012, ApJ 748, L14
Woods, T.N., Eparvier, F.G., Hock, R. et al. 2012, Solar Phys. 275, 115